Claims

1. A method for monitoring a high-resistivity reservoir rock formation (2) below one or more less resistive formations (3),
characterised in that
said method comprises the following steps:
transmitting an electromagnetic signal (S) propagating from near a seafloor or land surface (1) by means of an electromagnetic transmitter (5) powered by a voltage or current signal generator (G);
said electromagnetic signal (S) propagating from said seafloor or land surface (1) to said high-resistive formation (2) as a guided-wave electromagnetic signal (S_1) along a conductive string (7) in a well (7b), and further propagating as a guided-wave electromagnetic signal (S_2) inside said high-resistivity formation (2);
said electromagnetic signal (S_2) giving rise to an upward refracting electromagnetic signal (R_3) in said less resistive formations (3) and having an exit angle nearer to the normal N to the interface between said high-resistivity formation (2) and said lower-resistivity formation (3), and giving rise to a steeply rising refraction wave front (F_3);
detecting said refracted electromagnetic wave front (F_3) comprising refracted electromagnetic signals (R_3), along an array of sensor antennas (6a, 6b, 6c, ..., 6k, ..., 6n) along said seafloor, said array having a direction away from said transmitter (5).

2. A method according to claim 1,
characterised in that
said electromagnetic transmitter (5) comprises an antenna (50) transmitting said electromagnetic signal (S) to an upper end (70 U) of an electrically conductive string (7), e.g. a steel casing or liner, said upper end (70 U) being arranged near said seafloor (1).

3. A method according to claim 1,
characterised in that
an electromagnetic transmitter (5) is used, comprising electrodes (50A, 50B) of which one is connected to an upper end (70 U) of an electrically conductive string (7), said upper end (70 U) being arranged near said seafloor (1).

4. A method according to claim 2 or 3,
characterised in that
a lower end (70 L) of said electrically conductive string (7) penetrates at least an upper interface between said high-resistive formation (2) and the overlying lower-resistive formations (3).

5. A method according to claim 2 or 3,
characterised in that
a lower end (70 L) of said electrically conductive string (7) does not penetrate an upper interface between said high-resistive formation (2) and the overlying lower-resistive formations (3), but resides at a depth intermediate between said seafloor (1) and said high-resistive formation (2).

6. A method according to claim 2,
characterised in that
said antenna (50), transmits said electromagnetic signal (S) to said upper end (70 U) of said electrically conductive string (7), in which said antenna (50) being a toroidal antenna receiving electrical energy from said voltage signal generator (G).

7. Amethod according to claim 5,
characterised in that
said toroidal antenna (50) is arranged generally enveloping said upper end (70 U) of said electrically conductive string (7).

8. A method according to claim 5, **characterised in that** said toroidal antenna (50) is provided with a ring core (51) having high permeability.

9. A method according to claim 3, **characterised in that** said electrodes (50A, 50B), of which one electrode (50A or 50B) is connected to said upper end (70 U) of said electrically conductive string (7), for integrating part of said conducting string (7) for transmitting said electromagnetic signal (S), supplied with electrical energy from said voltage signal generator G) being a power supply generator.

10. A method according to claim 1, **characterised in that** said electrically conductive string (7) is a borehole casing being cemented to a borehole wall (7b) by means of cement (74) having a resistivity higher than said resistivity of said low-resistivity formation (3), said high-resistivity cement (74) providing improved waveguide properties for said electrically conductive string (7) through said low-resistivity formation (3) for a propagating EM signal along said conductive string (7).

11. A method according to claim 5 or 8, **characterised in that** said electromagnetic signal (S) has a frequency or frequencies in the range between 0,1 Hz and 1000 Hz.

12. A method according to claim 5 or 8, **characterised in that** the power supplied by said generator (G) is in the range between 10 W and 10 kW.

13. A method according to claim 1,
characterised in that
said method comprises detecting a strong apparent horizontal speed of said detected refracted electromagnetic wave front (F_3) along said seafloor as registered along said array of sensor antennas (6a, 6b, 6c, ..., 6k, ..., 6n) along said seafloor, in order to distinguish a first horizontally extending area (A1) having high resistivity indicating a presence of oil-wet or oil-saturated rocks of said formation (2), from a horizontal area (A2) of lower resistivity indicating a presence of water-wet or water-saturated rocks, possibly in the same geological formation.

14. A method according to claim 12,
characterised in that
the apparent horizontal speed of the received refracted signal wave front (F_3) is calculated on the basis of phase angle differences between the signal received at sensor antennas (6a, 6b, 6c, ..., 6k, ..., 6n) having different offsets along said seafloor.

15. A method according to claim 1,
characterised in that
said method comprises detecting a strong amplitude of said detected refracted electromagnetic wave front (F_3) along said seafloor as registered along said array of sensor antennas (6a, 6b, 6c, ..., 6k, ..., 6n) along said seafloor, in order to distinguish a first horizontal area (A1) having high resistivity indicating oil-wet or oil saturated rocks of said formation (2), from a horizontally extending area (A2) of lower resistivity indicating water-wet or water saturated rocks, possibly in the same geolocical formation.

16. A method for monitoring a subterranean petroleum-bearing formation (2) having lower relative resistivity and being buried under other rock formations (3) having higher relative resistivity, using polarized electromagnetic waves,
characterised in that
said method comprises the following steps:
arranging a transmitter antenna (5) comprising a pair of electrodes (50A, 50B) arranged in a borehole (7) crossing said petroleum bearing formation (2), said electrodes (50A, 50B) arranged above and below said petroleum bearing formation (2), respectively;
arranging one or more receiver antennas (6a, 6b, ... , 6n) along a seafloor (1) on a seafloor (1) above said rock formations (3), said antennas (6) for receiving electromagnetic waves;
emitting vertically polarized waves from said antenna (5) into said petroleum bearing formation (2); and
receiving refracted electromagnetic waves by means of said receiving antennas (6a, 6b, ... , 6n) arranged along said seafloor (1) on top of said formation (2);
for analyzing geometric properties of said petroleum bearing formation (2).

17. A method for stimulating petroleum production from a high-resistivity reservoir rock formation (2) below one or more less resistive formations (3),
characterised in that
said method comprises the following steps:
transmitting an electromagnetic signal (S) propagating from near a seafloor or land surface (1) by means of an electromagnetic transmitter (5) powered by a voltage signal generator (G);
said electromagnetic signal (S) propagating from said seafloor (1) through said high-resistive formation (2) via a conductive casing or drilling string or production string (7), and propagating as a guided-wave

electromagnetic signal (S_2) at a relatively higher speed (V_2) inside said high-resistivity formation (2) than a propagation speed (V_3) in said less resistive formations (3),

said electromagnetic signal (S) stimulating the petroleum mobility in said rock formation (2), in order for increasing petroleum production from said formation (2).